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DISEASES OF CABBAGE AND RELATED CROPS AND THEIR CONTROL.

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BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 30, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as a Farmers' Bulletin a manuscript entitled "Diseases of Cabbage and Related Crops and Their Control," by Mr. L. L. Harter, Pathologist in the Office of Cotton and Truck Disease and Sugar-Plant Investigations.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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DISEASES OF CABBAGE AND RELATED CROPS AND THEIR CONTROL.

INTRODUCTION.

Cabbage is one of the most widely distributed and cultivated of our farm crops and at the present time is found in the garden of nearly every farmer. As long as the crop was grown only for home consumption the various diseases which attack it attracted little or no attention. In more recent years, however, cabbage growing has become a very important industry and now exists on a commercial scale in many parts of the United States. With the extension of the industry the diseases of the crop have increased in severity to a degree where they have reached economic importance. Unless some means are employed to check them there is danger that the industry will be forced out of its present centers. Such an event would result in the loss of large sums of money by those men who have constructed and maintained large sauerkraut factories and storage houses and would deprive many farmers of a very profitable cultivated crop.

From the original wild stock of cabbage have come cauliflower, Brussels sprouts, kohl-rabi, collards, and kale. Other cultivated crucifers closely related to those already mentioned are turnips, radishes, rape, broccoli, rutabaga, and charlock. Among the related wild plants shepherd's purse, peppergrass, and mustard are of most frequent occurrence. Mustard is sometimes cultivated, but it grows so profusely under all conditions that it is perhaps better classed as an obnoxious weed.

Practically all the crucifers mentioned are subject to the same diseases, so that any method for the control of the diseases of cabbage or cauliflower, for example, can be applied to other crucifers as well.

CLASSIFICATION OF THE CABBAGE INDUSTRY.

There are five classes of farmers who engage in the cultivation of cabbage and who, therefore, are especially interested in the different diseases: (1) The farmer who cultivates a variety of crops and grows cabbage only for home use; (2) the trucker who grows an early

spring crop which is immediately sold on the market and consumed as a green vegetable; (3) the farmer who grows a late summer or fall crop for the sauerkraut manufacturers; (4) the farmer who grows a late crop for storage purposes; and (5) the seed grower.

The general farmers, with the exception of those who grow cabbage on a commercial scale, have at most only small patches, so that the aggregate total acreage grown by them is small. But the family garden used by the great majority of growers and limited to a small area upon which cabbage, cauliflower, or other crucifers are grown year after year on the same ground provides the most favorable conditions for the perpetuation of the various diseases.

The truckers are located mostly in the Southern States or in the Eastern States along the Atlantic seaboard in the vicinity of the large cities. In the Southern States the cabbage crop is planted in the fall, winter, or early spring, and after marketing is immediately followed by some other crop. In the more northern districts the crop is planted in the spring.

The trucker works the ground intensively, obtaining from the same land in a single year two, three, or even four different crops. According to the system of rotation generally followed cabbage would appear on the same ground about every second or third year.

The manufacture of sauerkraut forms an important industry in some of the Northern States, more particularly Ohio, Michigan, and Wisconsin. The manufacturers depend upon a late summer or fall crop. The yield of cabbage grown for this industry has been greatly reduced in recent years by the invasion of several destructive diseases which now threaten to exterminate it or force it out of its present centers.

In some of the Northern States, especially New York and Wisconsin, many farmers grow a late crop to be placed in storage to supply the winter demand for fresh cabbage. In these districts also the invasion of diseases has greatly reduced the yield. Diseased heads do not keep well when placed in storage. In an unfavorable season the yield in some of the districts where cold storage is practiced has been reduced 50 to 60 per cent. From 25 to 40 per cent of the heads that go into storage are frequently lost from decay or rendered unfit for marketing.

Most of the seed of cabbage, cauliflower, and related crops is grown either on Long Island, N. Y., or near Puget Sound, Wash., or is imported. It is especially important that it be grown on soil free from the diseases of all crucifers, since it is possible that some of the worst pests may be distributed to various parts of the country with the seed. The care with which the seed is produced, therefore, is of great importance to every farmer wishing to grow any of these crops.

HOW THE VARIOUS DISEASES ARE DISSEMINATED.

Fungous and bacterial diseases are carried from one place to another by various means, such as (1) insects, (2) infected seed, (3) transplanting from an infected seed bed to the field, (4) drainage water, (5) stable manure and compost, (6) animals, and (7) wind.

INSECTS.

Insects are potent factors in the distribution of some diseases. It has been shown that the bacteria causing the black-rot of cabbage have been carried from one plant to another and from one leaf to another by slugs, snails, etc. Insects which visit cabbage and other crucifers are likely to carry the germs on their bodies and deposit them on the parts of noninfected plants. If other conditions are favorable, infection then takes place.

Certain insects are attracted to diseased areas of plants by the odors emitted therefrom. Cabbage affected with clubroot has a very offensive odor at some stages in the development of the disease. Insects frequent the roots, and before the disease was thoroughly studied they were supposed to be the cause of it. Later observations, however, showed that they were attracted to the decayed roots by the odor and were in no way connected with the cause of the disease. New infections may be brought about by these insects visiting other plants.

INFECTED SEED.

Growers of cabbage for the market seldom raise their own seed, but purchase it from seed growers. The same can be said of cauliflower and other related plants. If the seed is grown where diseases are prevalent it is possible that the disease may be introduced with the seed. The germs of some of our worst plant diseases, the black-rot of cabbage in particular, have been found to live on the seed for several months. For this reason it is always advisable, as a precautionary measure, to treat the seed with some disinfectant before sowing. (See p. 9.)

TRANSPLANTING.

Plants that are started in a crowded seed bed, which is often located on old ground near the house or in the garden, are frequent carriers of diseases to a noninfected field. In such crowded conditions diseases are readily communicated from one plant to another. Some of the diseases of cabbage and cauliflower, such as clubroot, are known to be distributed to some extent by insects. The insects, burrowing through the ground or feeding upon the roots, carry the

disease from the roots of one plant to those of another. If care is exercised to prevent the disease in the seed bed by the proper disinfection of the seed and the seed bed before sowing, the loss in the field can be greatly reduced.

DRAINAGE WATER.

Drainage water or the run-off during heavy rains probably furnishes one of the most important means for the dissemination of plant diseases and has been found in many places to explain the presence of a disease in fields where cabbage or other crucifers have never before been grown. If the crop is planted on high ground the germs from the refuse of diseased plants may be washed to the low-lying fields during heavy rains. In the hope of avoiding the disease by crop rotation a new field on this low ground may be selected, where the disease will prove as severe as on the abandoned field.

In some sections where cabbage is grown on a commercial scale it is customary to set the plants with a machine which drops about a half pint of water for each plant. For this purpose the water from drainage ditches, which is often the run-off from a field where some bad disease has been present, being the most available, is frequently used. This use furnishes another method of spreading disease, as was illustrated in a field set to cabbage for the first time, which came under the writer's observation. The water used in setting a part of the field was obtained from a well; for the remainder, water from a drainage ditch adjacent to a field planted to cabbage the previous year was used. The plants set in both portions of the field were secured from the same seed bed. The wilt, or yellows, was very severe where the plants were set with water from the drainage ditch; the other part of the field was free from it.

STABLE MANURE AND COMPOST.

A not uncommon practice is for farmers to throw the refuse of cabbage or other crops on the manure heap, the compost thus formed being hauled out and distributed on the fields the following spring. This is a bad practice if the crop is diseased, as the causal organism may thereby be readily disseminated. The value of cabbage leaves as a fertilizer or, in fact, the leaves of any crucifers, is very doubtful. Cabbage leaves contain 85 to 90 per cent of water and the leaves of other crucifers nearly as much, so that even though all the dry matter might be valuable as a fertilizer it would be so small as to be practically negligible. Rather than take the risk of spreading some parasitic disease it would be far better to collect the refuse from infected fields and burn it.

DISTRIBUTION BY ANIMALS.

In order to avoid what may seem an apparent waste, farmers frequently turn their stock in the fields to feed upon any roughage that may be found after a crop is harvested. Cattle and sheep are especially fond of cabbage leaves and by eating them they may carry serious diseases to other fields, as the causal organism may pass unharmed through the alimentary canal. In addition to this the spores may be, and often are, carried on the feet of animals, so that free access to the whole farm increases the possibility of communicating diseases from one field to another.

DISSEMINATION BY WIND.

Dissemination by wind is perhaps not so important a factor in the distribution of diseases of cruciferous plants as some already mentioned. Nevertheless, in certain districts where the soil is light, where dry weather prevails a part of the year, and high winds are common, spores may be carried long distances. The diseases that are external to the leaves are more likely to be distributed in this way than parasites which are situated in the soil or in the internal portion of the plant.

FARM PRACTICE AND ITS RELATION TO THE CONTROL OF DISEASES.

Several methods by which diseases may be carried from one plant to another, from one field to another, or, indeed, from one part of the country to another have already been pointed out. In view of these facts the first aim of the farmer should be to prevent, if possible, the introduction and distribution of destructive diseases on his farm. In order to accomplish this several precautions should be observed, of which the more important are: (1) The disinfection of seed, (2) the preparation and care of the seed bed, (3) crop rotation, and (4) the application of fungicides.

DISINFECTION OF SEED.

Farmers who grow cabbage, cauliflower, and other crucifers as market-garden crops seldom produce their own seed. Seed growing is an industry in itself and requires quite different cultural methods from those necessary to grow a market crop. It has been found that certain soils and climates are better suited than others for seed production. Because of this fact most of the cabbage seed is grown on Long Island, or near Puget Sound, or is imported. The men engaged in this industry are not especially interested in obtaining seed free from disease germs, and it is possible that some of the worst diseases of these crops have been distributed from these centers by means of

the seed. The farmer, therefore, should guard against the introduction of dangerous maladies by disinfection of the seed before sowing it in the seed bed or in the field. "An ounce of prevention is worth a pound of cure." The seed of cabbage, cauliflower, turnips, and other crucifers should be disinfected according to the following method:

Formaldehyde (40 per cent)	½ pint.
Water	7 gallons.

The seed should be left in the solution about 15 minutes, dipped in pure water to wash off the formaldehyde, and then spread out to dry. Even greater strengths of formaldehyde can be used without injury to the seed if care is exercised to wash and dry thoroughly.

CARE AND PREPARATION OF THE SEED BED.

Cabbage, cauliflower, and some other plants of the same family are generally started in a seed bed before being set into the field. As previously pointed out, some of the worst diseases of these crops may be transferred by means of the plants from the seed bed to noninfected fields. In order to grow strong, vigorous plants as quickly as possible compost or stable manure is mixed with a good quality of soil to form the seed bed. The mistake is often made of placing the bed on an old cabbage field where diseases may have been present, because the soil happened to be fertile or for other reasons. Furthermore, the manure might be, and often is, taken from the heap where diseased plants have been thrown to compost, or it may be from animals that have fed on diseased cabbage. In either case there would be great danger of introducing the diseases into the seed bed. The transfer of such plants to the field would naturally mean the transfer of the diseases affecting them.

Mr. W. W. Gilbert, of the Bureau of Plant Industry, recommends the following methods for disinfecting the seed beds: (1) Steam sterilization by means of draintile laid in the bottom of the beds, through which steam is passed; (2) sterilization by means of an inverted pan under which steam is admitted; (3) sterilization by drenching the soil with a formalin solution; or (4) treating soil with Bordeaux mixture.

In the tile method of steaming, lines of 2-inch to 3-inch glazed tile are placed lengthwise in the beds to be sterilized, 2 to 2½ feet apart and 15 inches below the surface, and are left there permanently. They provide drainage for the beds, may be used for subirrigation, and are available at any time for sterilizing the soil, the only outlay for labor being the covering of the beds with boards or a tarpaulin and the connecting of the tile with a boiler by means of a piece of steam hose. The soil need not be moved, and thus a large part of

the labor involved in sterilization is obviated. It is advisable, however, to spade up the soil so that the steam may more readily penetrate it.

Another method of steaming, by means of an inverted galvanized-iron pan, 6 by 10 feet and 6 inches deep, under which steam is admitted, has been used to a limited extent in the sterilization of tobacco seed beds and in greenhouse beds and has given very satisfactory results. The use of steam at a pressure of 80 to 100 pounds and treatment for from one-half hour to an hour after the soil has reached a temperature of 212° F., as indicated by soil thermometers, has given the best results.

Formalin sterilization is accomplished by drenching the soil with a 1 to 100 or 1 to 200 solution of formalin, at the rate of three-fourths of a gallon per square foot of area, several days before the soil is to be used. Formalin, however, does not rid the soil of nematodes, as steaming does. This method has been used to good advantage in the sterilization of lettuce beds for the prevention of fungous diseases. For more detailed directions for soil sterilization by the methods here outlined, see Bulletin No. 158 of the Bureau of Plant Industry, entitled "The Root-Rot of Tobacco Caused by Thielavia Basicola."

Another method of soil sterilization in the seed bed, which the Ohio Agricultural Experiment Station has found successful in controlling the black-leg of cabbage, consists in treating the bed immediately after sowing the seed with a solution of Bordeaux mixture (4–4–50 formula) at the rate of 1 gallon per 10 square feet. In addition to this the beds should be sprayed about two weeks before and again just preceding transplanting into the field.

If it is found impracticable to disinfect the seed bed by any of the foregoing methods new soil should be used and stable manure, if mixed with it, should be obtained from some source where there is little or no chance for diseases to be present.

CROP ROTATION.

Crop rotation is an essential practice whether or not it is necessary in the control of any plant maladies. There are numerous fungous diseases which reappear year after year on the same field if a suitable host is present. Some of them, such as the clubroot of cabbage, are strictly soil parasites and can not be controlled by any fungicide. About the only method left to get rid of the organism is to starve it out, and this can be done only by a well-planned system of crop rotation. Most of the organisms like the clubroot of cabbage have a number of hosts on which they live, any one of which will serve to perpetuate the disease. It is therefore necessary to avoid planting in close succession crops that are affected with the same parasites.

The length of the rotation depends largely upon the disease and the thoroughness with which the system is carried out. There are only a few diseases that will be killed out by a three or four year rotation, and instances are known where one of six or seven years has failed to eradicate the malady, though its severity was greatly reduced. There are several reasons why long rotations are frequently necessary. (1) Many weeds which are overlooked by the farmer during cultivation perpetuate the diseases. (2) Certain parasites are able to live for a time on decayed vegetative matter when a suitable host is not available. Just to what extent this is the case is not definitely known. (3) Some fungi have the ability to remain dormant for a considerable length of time in the absence of a suitable host. The organism causing the wilt of cabbage, for example, has been known to be dormant in dry soil for three and one-half years and then to produce the disease. For ordinary practice, however, a rotation of four or five years is sufficient to reduce greatly the loss from most parasites. Deep and frequent cultivation by means of which the organisms are exposed to the air and sunshine assists in exterminating them.

FUNGICIDES.

The leaf diseases of cabbage, cauliflower, and related crops are relatively so unimportant that spraying is seldom required. The most important diseases are internal or soil parasites and out of the reach of fungicides.

IMPORTANT CABBAGE AND CRUCIFEROUS DISEASES.[1]

CLASSIFICATION.

The following is a classification of the most important diseases of cabbage and cruciferous plants, with the pages of this bulletin on which they are discussed:

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DISEASES OF THE ROOT:	
Clubroot (clubfoot, finger and toe)	13
Root-knot (nematodes)	14
DISEASES AFFECTING ROOT, STEM, AND LEAVES:	
Black-rot (brown-rot, stem-rot, dry-rot)	16
Wilt (yellows, yellow-sides)	18
Black-leg (foot-rot, wilt)	21
Soft-rot	24
Malnutrition	25
DISEASES OF THE LEAF ONLY:	
Downy mildew	29
White-rust	30
Spot disease of cauliflower	30
Leaf-blight (black mold)	31
Powdery mildew	31
DISEASES OF YOUNG SEEDLINGS:	
Damping-off	31

[1] Various names are often applied to the same disease, as shown in this classification.

CLUBROOT (CLUBFOOT, FINGER AND TOE).

Description.—Plants affected with clubroot, even in the presence of abundant moisture, show in the earlier stages a wilting of the foliage in the sunshine, which recovers toward evening or when cloudy weather comes on. They are characterized by malformations of the roots in the form of swellings (fig. 1), sometimes as large as two fists. Few or no lateral feeding roots are formed. The disease generally attacks the plants when young, often in the seed bed, and plants so affected have a stunted, sickly appearance. Diseased plants seldom grow to maturity. The clubroot of crucifers might be confused with root-knot, which is characterized by similar enlargements of the roots caused by a minute eelworm, or nematode. The malformations caused by nematodes, however, are usually not so large. While present to some extent in the North, especially in greenhouses, root-knot is more commonly met with in the South. Clubroot, on the other hand, is more prevalent in the Northern States.

FIG. 1. Enlarged roots of cauliflower caused by the clubroot organism.

Control.—The clubroot organism is a soil parasite and for that reason recourse must be made to some form of soil treatment. The organism thrives best in an "acid" soil and in view of this fact slaked lime at the rate of about 75 bushels per acre added every few years will keep the disease in check. The lime should be added some months before planting. If the crop is to be planted early in the spring the lime should be applied the previous fall, but if a late planting is desired it can be put on in the spring.

Seedlings are very susceptible to the disease, and the utmost precaution must be taken to grow the plants on uninfected soil, or disinfection of the seed bed should be practiced. Furthermore, diseased plants should be destroyed by burning and should not be thrown on the manure pile or left in the field. Crop rotation should be practiced, and as it has been found that the disease will live in the soil for several years the rotation should be a long one. All cruciferous weeds should be destroyed, and no cultivated crucifers should be used in the rotation. The disease has been found in this country on cabbage, cauliflower, rutabaga, turnips, radishes, Brussels sprouts, and mustard among the cultivated plants and on some of the weeds of the same family. It probably occurs on many others.

No variety of these crops is known to be positively resistant to clubroot, though the Hollander variety of cabbage is claimed by some growers to be partially resistant. It has also been observed that the varieties of blue or red cabbage are less susceptible to clubroot than the Succession variety. Unfortunately, however, though apparently more resistant, these colored types are not good for all commercial purposes as, for example, the manufacture of sauerkraut.

Distribution and loss.—Clubroot has been known in Europe for more than a century. It occurs in England, Holland, Russia, and other European countries. Its presence in Australia has been known for a number of years. It has also been reported from New Zealand and from 20 States in this country and probably occurs in many more. It is present over most of the country east of the Mississippi River.

In some seasons from 40 to 50 per cent of the crop in the affected fields is lost by this disease. As early as 1876 Woronin estimated the loss near St. Petersburg, Russia, at more than $200,000.

Cause. Although clubroot was known to occur in Europe more than a century ago, its true cause was not known until 1876, when Woronin, a Russian botanist, found it to be due to a slime mold, one of the lowest forms of life, and gave it the name *Plasmodiophora brassicae* Wor. Previous to that time, insects were suspected to be the cause of the disease, largely because they were frequently present in the swellings of the roots. It is now known that they are attracted by the odor of the decaying roots.

The slime mold causing clubroot is composed of a plasmodium, or mass of motile protoplasm, situated within the tissue of the host. The plasmodium subsequently breaks up into innumerable microscopic spherical spores. Upon the germination of these spores the contents escape as irregular protoplasmic masses (zoospores). This is sometimes spoken of or called the swarm-spore stage. The zoospores are provided with a cilium, a tail-like appendage, by means of which they propel themselves from one place to another. In their unprotected state the zoospores can not survive long, so they must either find a suitable host or perish. When they come in contact with the proper host they enter the tender roots and form anew the plasmodium.

ROOT-KNOT (NEMATODES).

Description. Some confusion is likely to result in trying to distinguish between root-knot and clubroot. While the organisms causing the two diseases are quite different, the effects produced on

the roots bear some points of resemblance. (Compare figs. 1 and 2.) Root-knot, as a rule, is characterized by smaller swellings than clubroot, more of the lateral feeding roots are affected, and the nodules are located nearer the tips of the roots. If upon breaking open the swellings on the roots pearly white bodies about the size of a pinhead are found, root-knot is to be suspected. These white specks within the swellings are the enlarged egg-bearing female eelworms, which cause the disease. The interior mass of clubroot is slightly pinkish or brick colored. Root-knot affects a great variety of unrelated plants, while clubroot, so far as known, occurs only on crucifers.

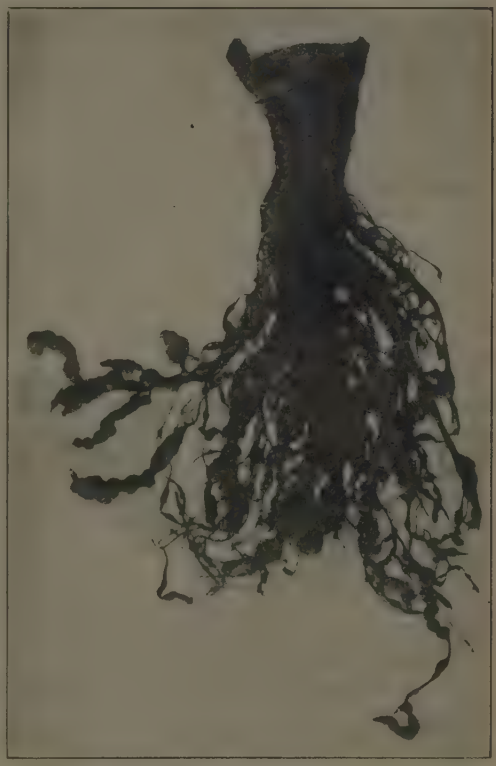

FIG. 2.—Enlarged roots of cabbage caused by nematodes.

Furthermore, root-knot is confined largely to the light, sandy soils in the South, although it may occur in the Northern States, while clubroot is seldom found in the South and may occur on either heavy or light soil.

Control.—Crop rotation has been found to be a most effective means of controlling this disease, the object being to use crops immune to root-knot for the purpose of starving out the worms. When this method of eradicating the disease is employed, a rotation of at least three years, accompanied by clean cultivation, should be practiced. There are some 480 different species of plants already known to be susceptible to root-knot, among which are many cultivated plants and numerous weeds. Crops known to be immune to the disease that can be used in the rotation are corn, oats, rye, timothy, pearl millet, sorghum, wheat, crab-grass, the Iron cowpea,

velvet beans, peanuts, and beggarweed. Some of the cultivated crops susceptible to the disease and therefore to be avoided in the rotation are alfalfa, vetch, soy beans, cowpeas (except the Iron), clover, sugar cane, tomatoes, okra, cucumbers, cantaloupes, watermelons, celery, beans, sweet potatoes, tobacco, potatoes, peaches, figs, mulberries, and all crucifers.

If the disease occurs in the seed bed or greenhouse the soil should be sterilized by live steam in accordance with one of the methods referred to on page 10 or by treating the soil with a solution of formaldehyde (1 part of commercial formaldehyde to 100 parts of water) at the rate of 1 to 1½ gallons to every square yard of soil surface. When this latter method is used, about 10 days should elapse between the time of treating and of sowing the seed in order to allow the formaldehyde to evaporate from the soil. It is advisable to stir the soil occasionally during this time.

Distribution and loss.—Nematodes on different crops have been found widely distributed, but more especially in the tropical and subtropical climates. Their greater abundance in warm climates indicates that they are natives of the Tropics, and when found in the colder climates they have probably been introduced. The total loss caused by nematodes is very great, much more than is generally appreciated.

Cause.—Root-knot is caused by a parasitic eelworm (*Heterodera radicicola* (Greef) Müll.) one-twentieth to one-sixtieth of an inch in length. It penetrates the small roots and causes irregular swellings of various sizes. The nematode enters the roots in the larval stage. It then becomes motionless and gradually enlarges. After its entrance into the host changes take place, the male retaining the worm shape and the female becoming pear shaped. Each female lays several hundred eggs. Under favorable conditions a full life cycle can be completed in about four weeks. Nematodes migrate slowly in the soil the distance covered in a single year probably not amounting to more than 1 or 2 yards. They are dependent upon foreign agencies for means of wide distribution. Nematodes probably pass the winter in the soil in the larval stage, though it is claimed that they winter in the roots of perennial plants in the mature stage. For a fuller discussion of this subject, see Bulletin 217 of the Bureau of Plant Industry, entitled "Root-Knot and Its Control."

BLACK-ROT (BROWN-ROT, STEM-ROT, DRY-ROT).

Description.—Of the symptoms of the black-rot Dr. Erwin F. Smith says:[1]

> The disease may appear in the plant at any stage of growth and is characterized by the following symptoms: Dwarfing, or one-sided growth of the heads, or, if the disease is very severe and has begun early in the season, by the entire absence of any head, and in extreme cases by the death of the plant. Occasionally the heads rot and fall off, but this is not a necessary consequence, the soft, bad-smelling rot being due to the entrance of other organisms. If the stumps of affected plants are broken or cut across, a brown or black ring will be observed, corresponding to the woody part of the stem, this part of the stem being especially subject to the disease. In bad cases this blackening may be easily traced upward into the center of the head and is generally worse on one side.

[1] Smith, Erwin F. The Black Rot of the Cabbage. Farmers' Bulletin 68, 1898, pp. 5-6.

Infection usually takes place at the margin of the leaf. The progress of the disease from the point of infection can frequently be traced through the veins of the leaf by the blackening of the bundles. The marginal infection is later followed by a browning and drying up of the infected areas of the leaf.

Control.—It is to be regretted that no sure methods for controlling black-rot are known, but the observance of certain precautions will prevent serious loss from this very destructive disease. (1) All seed should be disinfected before sowing, in accordance with the method described on page 9. (2) Care should be exercised in the preparation of the seed bed, and only manure and soil should be used that are known to be free from the disease. (3) Crop rotation, whether for the prevention of disease or not, is always a good practice. In connection with black-rot it is very important. To control the disease by this method the rotation should be one in which no cultivated crucifers or cruciferous weeds are allowed to grow in the ground for four or five years. (4) Insects slugs, snails, etc., by crawling from infected to noninfected plants carry black-rot organisms; when possible, they should be kept in subjection. (5) Live stock should not be allowed to roam at will over diseased cabbage patches, as they may carry the organisms to noninfected fields. (6) Diseased plants as soon as detected should be pulled up and destroyed and not thrown on the manure heap to compost.

Distribution and loss.—Black-rot has been reported from many States east of the Mississippi River and from a few west of it. For 20 years or more it has been destructive in the States of Ohio, Wisconsin, Michigan, and New York. In recent years several other States, particularly Virginia, Iowa, New Jersey, and Texas, have reported outbreaks. The disease has been injurious to cabbage as far south as Florida, and extends through all the States north into Canada. In 1908 it was reported from the State of Washington, but it has not occurred to our knowledge in any of the Rocky Mountain States with the exception of Colorado and Arizona. It is also well known in almost all parts of Europe and has been reported from the islands of Cuba, Porto Rico, and New Zealand.

The loss to cabbage and related plants from black-rot probably exceeds that of any one of the other diseases. It does not end in the field. It often happens that an apparently sound head is found to be rotten inside. The difficulty of detecting such heads and the fact that some are overlooked in handling result in placing many in storage, where they further decay.

Cause.—Black-rot is caused by a yellow bacterium (*Bacterium campestre* (Pammel) Erw. Sm.). Infection takes place through the leaves and occasionally through the roots. When infection takes place through the roots the organism spreads throughout the plant by following up the fibrovascular bundles of the stem (fig. 3). Probably

most of the infections, however, take place at the margins of the leaves, either through punctures made by leaf-sucking insects or in the small droplets of water which collect at the margins of the leaves during cool nights and in damp, rainy weather. The organisms then find their way into the interior of the plant.

It is not positively known how the organisms get to the points of infection on the leaf, but presumably they are carried there on the bodies of insects or lodged on the leaf from the dust in the air. The progress of the disease from the point of infection is inward and downward. If follows the bundles of the leaf. The portion of the leaf around the point of infection, except the fibrovascular bundles, first turns yellow, then brown, and finally dries up. The veins of an infected leaf are black. Infection may take place at several points on the same leaf and on several leaves of the same plant. In the course of time the disease advances to the base of the leaf and enters the stem, from which point it may infect many other leaves and work up through the center of the head.

FIG. 3. Sections through a cabbage stem showing the conspicuous ring of black bundles caused by the black-rot organism.

WILT (YELLOWS, YELLOW-SIDES).

Description.—So far as known cabbage is the only crop affected by the form of wilt known as "yellows" or "yellow-sides." The plants usually show the characteristic symptoms in about two to four weeks after they are set in the field, but often the disease appears early in their growth in the seed bed. The outer and lower leaves are the first to show the signs of the disease. The whole leaf may first turn yellow between the veins and around the margins, and then later brown, as if scorched, and finally drop off; or only one side of the leaf may dry up, while the other half remains normal. This latter symptom is the more usual and is a distinguishing characteristic of the disease; little or no wilting of the plant is then apparent and for that reason "yellows"

is a better descriptive term than wilt. The lowest leaf is always the first to drop off, and this is followed by the next above, until only a

FIG 4.—A cabbage plant showing the characteristic symptoms of wilt or yellows.

bare stock is left, supporting a small imperfect head or none at all, depending upon the age of the plant when it became diseased (fig. 4).

Subsequent to the dropping of the leaves short sprouts from one-half inch to 1½ inches long sometimes grow out between the leaf scars.

Browning of the woody portion of the stem is another characteristic of wilt, and if the stem is cut off with a sharp knife a black ring corresponding to the fibrovascular bundles may be seen.

Control.—The seed should be disinfected according to the method already described on page 9. Wilt has been found to occur in many seed beds, and for that reason manure and soil known to be free from the disease should be used. Sterilization of the seed bed should be practiced whenever possible. It has been found that even though the seed bed has been sterilized and noninfected plants obtained they may become diseased later if planted out in infected soil.

The plants evidently become diseased when quite young, and many can be detected before planting. Such should be pulled out and destroyed. Lessen the possibility of spreading the disease by destroying all diseased plants. Do not allow stock to roam at will over the fields. When water is used for setting it should be taken from wells instead of from drainage ditches, which are liable to be infected.

Crop rotation should be practiced. The organism causing wilt can live several years in the soil; hence, the rotation should cover a period of four to eight years.

Distribution and loss.—The organism causing wilt has been isolated from cabbage material received from the following States: North Carolina, South Carolina, Georgia, Mississippi, Maryland, Virginia, New York, Wisconsin, Ohio, and Michigan. It is possible that many cases of disease have been attributed to black-rot that in reality were due to wilt. The two diseases have often been found associated, and both organisms have frequently been isolated from the same plant.

Not until recent years has the loss from this disease been large in any one district, but serious results can be looked for in the future unless care is exercised to prevent its spread. The disease has been worse in Ohio than in any other State, the loss in one locality alone amounting to several thousand dollars annually. In Maryland and other States it has attracted some attention for several years.

Cause.—Wilt of cabbage is caused by a microscopic organism, Fusarium, the species of which has never been described. This group of fungi is only imperfectly known. Some are parasitic, while others are known to be only saprophytic, viz, organisms which live exclusively on dead vegetable matter.

Infection of the host undoubtedly takes place through the roots. Injuries to the roots made by insects may help to infect the plants, but such means are not necessary. The writer has caused the disease by inoculation of the soil in which the plants were growing, care being exercised not to injure the roots.

The vegetative part of the fungus consists of minute colorless threads called the mycelium. The fungus develops rapidly and after entering the roots grows up into the bundles of the stem, where it forms an almost impervious barrier to the water passing from the roots to the leaves.

Two forms of reproductive bodies are known. (1) The conidia, which are two to several-celled and sickle shaped. They are not formed in the interior of the host, but on the surface of the plant. A single spore under the microscope is colorless, but in mass they are pinkish. Often in pustules similar and sometimes within the pustules of the host, small, oval, one-celled spores are developed. Such stages of conidia are supposed to be developed only under abnormal conditions. (2) Chlamydospores, which germ are resistant, thick walled, and able to stand severe and disadvantageous conditions. They are formed on the end of a hyphia, or as a swelling of the mycelium on the surface of the host or in the soil.

It is probable that this fungus, like many others of the same form, multiplies a saprophytic, but has adapted itself to parasitic habits. If so it is the case it can live in the soil for some time in the soil until it comes in contact with a suitable host.

Many species of Fusarium cause numerous diseases of many crops. Among the most widely known and commonly met with are the dry-rot of potatoes, the scab of wheat, and the wilt of flax, cotton, and cowpeas. Tomatoes are also affected with a similar disease as yet undescribed.

Differences between most of these diseases are established only after cross inoculations involving extensive botanical work. The cabbage-wilt fungus has not been inoculated into other plants, so that it is not known whether this species of Fusarium causes diseases of other crops.

BLACK-LEG FOOT-ROT, WILT.

Description.—So far as known black-leg occurs only on cabbage and cauliflower and may attack the plants at any time in their growth, but more commonly when young. The earliest symptoms are usually seen in the seed beds two or three weeks before the time to set the plants in the field.

Infection frequently takes place on the stem at the surface of the ground just below the attachment of the leaves where lesions, abrasions, or sunken areas irregular in outline occur on the epidermis or it may take place at the margin of the leaves at the end of the larger veins, probably by means of the droplets of water that collect there during the night or in damp weather. Sunken spots or abrasions frequently occur also on the petiole of the leaf or on the midrib. At Norfolk, Va., where this disease caused heavy loss to the cabbage crop during the spring of 1911, infection through the leaf was very common. This mode of infection was less common in other districts where the disease has been observed. Insects were found associated to some extent with black-leg in Virginia, and the writer is inclined to believe that they assist in its spread. Numerous diseased plants, however, were found which showed no evidence of insect injury. The disease spreads from the point where the stem is infected downward to the roots and around the stem, often completely girdling it. If the plant is pulled up the small fibrous roots will be found more or less completely killed, and in advanced cases all the lateral roots will have rotted off. Before the death of the plant takes place a purplish tint is developed in the foliage which persists until the plant dies. This coloration constitutes one of the principal symptoms of the disease

Numerous minute black specks (pycnidia) a little larger than a pin point may be found scattered indiscriminately on the stem and leaves, in and about the lesions or abrasions caused by the black-leg fungus. (See fig. 5.) The pycnidia are filled with myriads of spores which serve to disseminate the disease.

FIG. 5.—A cabbage leaf showing injury from the black-leg organism.

Wilting of the whole plant is very characteristic of black-leg of cabbage. The leaves, instead of falling off, adhere to the stem and droop down as though suffering for water.

Control.—Cabbage black-leg is harbored for the most part in the soil on the decayed stems and leaves of the plants. In view of this fact the seed bed should not be located on land where the disease has occurred. The methods of controlling black-leg adopted should be those of prevention rather than cure. After selecting a suitable place for the seed bed, manure should be obtained from some source where cabbage stems and leaves have not been thrown to compost, since they are often a source of infection. The Ohio Agricultural Experiment Station has studied this disease in that State and recommends treating the seed beds with Bordeaux mixture (4-4-50 formula) at the rate of one gallon per 10 square feet, just after sowing the seed. A second treatment should be given two weeks before and a third just preceding the setting of the plants in the field. It is claimed by the Ohio station that this method of treatment will keep the disease down in the seed bed and prevent its appearance in the field.

The prevention of black-leg in the seed bed is of the greatest importance in restricting its spread. However, many fields in some localities are already infected, and the disease can be eradicated from them only by care and perseverance. All diseased plants should be burned. Cattle, horses, and other stock should not be allowed to roam from diseased patches into noninfected fields. Crop rotation should be practiced, and the seed should be disinfected in accordance with the formula given on page 9.

The writer's own experience has shown that steam sterilization of the soil for one hour at a temperature of 212° F. will prevent the disease in the seed bed.

Distribution and loss.—Cabbage black-leg occurs in Holland, France, and South Australia. It is not known to be widely distributed in this country, but was found on cabbage in 1910 in the States of Ohio, Michigan, and Iowa and occurred abundantly in Virginia during the spring of 1911. It was reported in 1911 on cabbage from Wisconsin and New York and on cauliflower from Louisiana. It probably also occurs in other States.

The loss occasioned by black-leg varies greatly in different localities and in different fields. The writer saw fields in Ohio where 60 per cent of the crop was destroyed by this disease alone and others where the loss would not exceed 5 per cent. (See fig. 6.) It was found in fields where cabbage had never before been grown, while some old fields had comparatively little of the disease. Only a few cases were found in Michigan, and the loss from the trouble was negligible. In Iowa it was quite prevalent in certain sections, and the loss was considerable. The disease was found to be more destructive in the trucking sections of tidewater Virginia than in any of the other States. It was so severe that in a few fields no marketable cabbage was cut; in some the loss amounted to as much as 75 per cent of the crop, while in others the disease did not occur.

Cause.—Black-leg is caused by a fungus (*Phoma oleracea* Sacc.).

Infection takes place on the stem near the ground, probably in wounds made by insects, and spreads from that point around the stem, down into the roots, and up to the leaves. Leaf infections also occur at the margins, generally at the ends of the larger veins.

The fruiting bodies of the fungus appear as black specks (pycnidia) in the lesions and abrasions. In the pycnidia are formed myriads of microscopic one-celled spores which upon oozing out are exposed to the winds, insects, and other foreign agencies, by which means they are probably carried to other plants. Wet weather is favorable for the spread of the disease, the greatest loss being occasioned during a wet season.

FIG. 6.—A field of cabbage with 75 per cent of the plants killed by the black-leg fungus.

In Australia cauliflower is injured severely by the same disease. The writer has not seen cauliflower attacked in the field by this organism, but has produced the disease in the greenhouse with ease by means of artificial inoculations.

SOFT-ROT.

Description.—Soft-rot of crucifers is characterized by a soft, mushy, almost slimy decay, which after entering, generally at the crown or root tip, spreads rapidly throughout the whole plant. The

soft-rot bacteria as a class are marked by their ability to destroy plants very quickly under favorable temperature conditions. They seldom affect uninjured plants, but require a wound or other injury to gain a foothold. Infection takes place in the field, where considerable damage has been occasioned, but the greatest destruction to this crop is caused in the cabbage storage houses. Under improper storage conditions the disease spreads rapidly, frequently covering all the outer leaves. The slime formed under these conditions is very unsightly and consequently affects the market value, even though only slight injury is caused.

Control.—Fields where the disease is known to occur should be avoided and rotation practiced with crops not injured by soft-rot organisms. It has been found that in the storage house, where the maximum loss occurs, an increase of the temperature much above the freezing point and a high percentage of humidity will result in rapid decay. In view of this fact it is advisable that a temperature should be maintained uniformly 1 or 2 degrees above freezing and the relative humidity kept near that of the outdoor air by careful ventilation. Furthermore, cabbage and other crops when going into storage should be handled carefully, so that they will be injured as little as possible. Since the soft-rot organisms are especially sensitive to light and drying, the crop should be thoroughly dried in the sunshine before being put into storage.

Distribution and loss.—The loss from soft-rot is considerable, especially in storage houses, where 25 to 50 per cent or more of the crop has been destroyed in a single season. The greatest loss occurs in New York and Wisconsin, where the storage of cabbage forms an important industry.

Cause.—Soft-rot of various crops is due to a group of closely related bacteria, *Bacillus carotovorous*, named and studied by Prof. L. R. Jones at the Vermont Agricultural Experiment Station, was found to affect a wide range of plants, such as turnips, onions, celery, radishes, carrots, and tomatoes. Mr. F. C. Harrison, of the Ontario Agricultural Experiment Station, Guelph, Canada, found a soft-rot organism destroying cauliflower, cabbage, and turnips, and called it *Bacillus oleracea*.

MALNUTRITION, A PHYSIOLOGICAL DISEASE.

Malnutrition is a trouble which affects cabbage, cauliflower, and other crops, especially in the Southern States. It is quite different from any of the diseases previously discussed, all of which are caused by parasites. By malnutrition is meant a disturbance of the normal functions of a plant which may be a result of its inability to obtain the proper nutrient substances from the soil. Malnutrition may be caused in several ways, such as the use of excessive mineral fertilizers, lack of humus, accumulation of acids in the soil, and the lack of nitrifying organisms.

Description.—The most characteristic symptom of malnutrition is a change of the normal green of the leaves to a light green or yellow between the veins and around the margins. (See fig. 7.) The lower leaves are the first to show symptoms, then the upper and

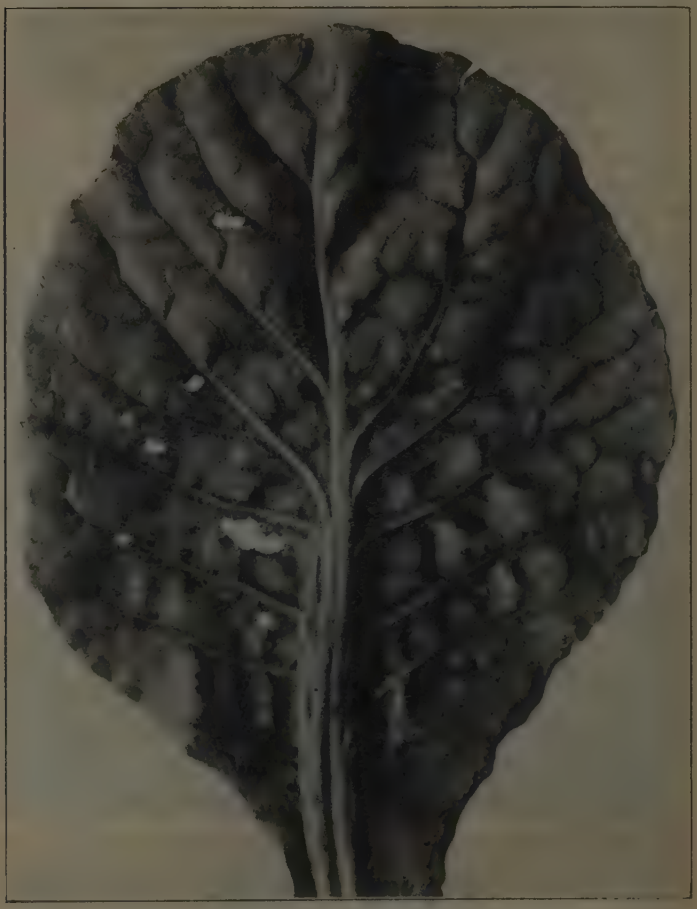

FIG. 7.—A cabbage leaf showing the characteristic symptoms of malnutrition.

inner ones. All diseased leaves are perceptibly thickened and so brittle as to be easily crushed between the fingers.

The heads from plants slightly affected are small and immature; when plants are badly diseased no heads are formed.

The roots are small and the lateral feeders few in number and frequently dead at the extreme end. Often the epidermis of the stem at the surface of the soil is injured, closely resembling the corrosive action of some acids and alkalies.

Control.—In controlling malnutrition four points need consideration: (1) Limitation of the quantity of fertilizers used; (2) adjustment of the composition of the fertilizer to meet the crop requirements; (3) the rational use of lime; and (4) the maintenance of the organic matter of the soil.

Practice on the part of farmers tends to increase the quantity of fertilizers when the preceding crop was poor, in the belief that the yield can in this way be maintained. This practice is not always the best. As a result of the writer's experiments on early cabbage in Virginia covering a period of three years, it was shown that better yields could be obtained from 1,000 pounds per acre of mineral fertilizer than from any larger amount up to 4,500 pounds, which gave the smallest yield of all. For the cabbage crop this is a saving of about 1 ton of fertilizer per acre, representing a value of about $35.

The composition of the fertilizer or the ratio of the different substances composing it is likewise very important in connection with malnutrition diseases. Where maladies of this sort occur, a fertilizer for cabbage and cauliflower should be derived from sources that will give an alkaline rather than an acid reaction. It has been found that an acid soil is likely to cause the disease and that these crops have been restored to a normal condition when lime was added. For a fertilizer which will meet the above requirement the nitrogen should be derived from nitrate of soda, fish scrap, or dried blood; the phosphorus from bone or Thomas slag; and the potash from the sulphate or carbonate of potash and not from the muriate.

Lime is not ordinarily needed as a plant food. It is used merely as a soil corrective. In the Southern States where mineral fertilizers are extensively used, the soils are very deficient in lime. Some of these soils are so acid as to require 15,000 pounds of slaked lime per acre to neutralize them to the depth of 1 foot. Scarcely any long-cultivated fields have been found to require less than 3,000 to 5,000 pounds. Even on the soils requiring the lesser quantities of lime, crops would not grow vigorously, and in the most acid soil the yields are greatly reduced and the plants injured in various ways. The full lime requirements need not be satisfied. Experiments have shown that the yield of cabbage can be increased several times by the addition of only 1,000 to 2,000 pounds of lime on soils requiring 8,000 pounds per acre to neutralize them as compared with other parts of the same field similarly fertilized but unlimed. While the striking increase in yield is probably due to a large extent directly to a neutralization of the acid in the soil, lime serves other pur-

poses. Among the other more important effects of liming soil the following may be mentioned: (1) To render available certain forms of plant food, especially compounds containing potassium; (2) to facilitate the decomposition of organic matter by encouraging the growth of micro-organisms; (3) to promote the growth of organisms that gather nitrogen from the air; and (4) to improve the physical texture of the soil.

The old cultivated fields of the South at the present time are ordinarily deficient in humus or organic matter, a condition for which mineral fertilizers are largely responsible. The yields from the use of fertilizers were so satisfactory for a long time that the farmer came to believe that this was all that was necessary to produce crops. In view of this fact the organic matter of the soil was disregarded, and it gradually became exhausted, so that at the present time fields that contain 0.50 per cent or less of humus are not uncommon, while 3 to 5 per cent should be present.

It is now found necessary to restore humus before fair yields can be expected. Humus can be supplied by the use of stable manure or by growing green-manure crops such as cowpeas, soy beans, vetches, etc., to be turned under when mature. The results from this method of restoring natural fertility to the soil are ordinarily very marked on the first succeeding crop.

Distribution and loss.—Malnutrition diseases are confined principally to those localities where mineral fertilizers are used for the production of larger and earlier crops. The disease, therefore, is restricted mostly to the Southern States. In general these soils are poor, respond quickly to fertilizers, and have been intensively and carelessly farmed for many years. The loss from this trouble, though large, can not be accurately estimated.

Cause.—Constant, clean cultivation for many years has robbed the soil of most of its original fertility. The farmers, therefore, naturally turned to the use of commercial fertilizers as a substitute. The results for many years were very gratifying. At the outset better crops were obtained than was possible on the best soils without fertilizers. This led the farmers to believe that fertilizers alone were necessary on any soil and the more used the greater the yield. When the returns gradually decreased as a result of this practice the quantity applied was gradually increased until it was not uncommon to add as much as 3,000 pounds of mineral fertilizers per acre for a single crop of cabbage. A large part of the fertilizer applied was not used by the plants, but remained in the soil where in the course of a number of years a considerable quantity accumulated.

It is a well-known fact that the salts comprising mineral fertilizers are poisonous to plants when used in excessive quantities. Some fertilizers have an acid reaction and eventually cause what is popularly known as a "sour soil." On the other hand, a small quantity of acid in the soil is not generally injurious, but it is not uncommon to find soil in the South so acid as to require 5,000 to 9,000 or more pounds of lime per acre to neutralize it. No agricultural plants will give their best yield under such conditions.

During the years when mineral fertilizers gave good results no attention was paid to maintaining the humus in the soil; consequently it soon became exhausted. In the presence of a large quantity of acid accumulated in the soil from the use of mineral fertilizers and the absence of humus the nitrifying bacteria and other beneficial organisms could not thrive. If legumes were planted no nitrogen was gathered from the air, and what vegetative matter was left on the ground remained in an undecayed state. A bacteriological examination of some of these soils has shown that the beneficial organisms are wanting or lacking in power to act. The addition of larger quantities of mineral fertilizers did no good but rather increased the loss, the plants being in a state of starvation even in the presence of abundant food.

Briefly summarized, malnutrition in truck crops is caused by the excessive use of mineral fertilizers and the absence of humus and of nitrifying bacteria.

DOWNY MILDEW.

Description.—Downy mildew first appears in the spring as a whitish mold in isolated spots on the under sides of the leaves. It may also occur on the stems. At the close of the season the portion of the leaf immediately surrounding the diseased area appears yellow and later turns brown and dries up. Frequently, light areas are observed in the center of a dark ring, which in turn is surrounded by a light or yellow area, thus presenting a conspicuous mottled appearance.

Control.—Downy mildew is seldom so troublesome as to require remedial measures, but when treatment is necessary it should be observed that all cruciferous weeds are attacked by this organism. Such weeds are sources of infection to cabbage and related crops and should be kept down. Any plants found diseased in the seed bed should be destroyed, not planted. The remains from diseased plants should be destroyed, as they serve to carry the resting spores over the winter. Crop rotation should be practiced. The plants should not be grown too thick, nor kept too wet in the seed bed. The plants in the seed bed should be sprayed about once a week with Bordeaux mixture (4–4–50 formula).

Distribution and loss.—Downy mildew seldom causes any serious loss except in seed beds. It has been found in Australia and Europe and has been reported from several States in the United States. It undoubtedly occurs wherever cabbage is grown, but owing to the fact that it causes but little loss to the crops it has not been reported.

Cause.—Downy mildew (*Peronospora parasitica* (Pers.) De By.) attacks all crucifers and causes distortions and abnormal growth. Two forms of spores or reproductive bodies are formed. The asexual spore is borne in the air on the end of branched conidiophores. The spores or reproductive bodies, when germinating, send out hyphæ which enter the stomata (breathing pores) of the host. The mycelium, or vegetative portion of the fungus, lives entirely within the host. The spores are formed in great numbers and are readily carried from one host to another by a gentle breeze or by insects. The disease is carried over the winter by means of yellowish, thick-walled, resting spores which are able to withstand unfavorable conditions until spring, when they germinate and reestablish the disease.

WHITE-RUST.

Young plants are more subject to attack, but the damage to cruciferous crops from white-rust is ordinarily very slight. The disease may occur on any part of the plant above ground, but more frequently on the leaves, where the tissue is often stimulated to distorted and abnormal growth. Moist, cloudy weather furnishes suitable conditions for the spread and growth of this disease.

Control.—Control measures are rarely necessary; if required, spray the plants in the seed bed once each week with Bordeaux mixture (4–4–50 formula). The seed bed should not be kept too moist. Set only healthy plants in the fields and destroy all others.

Distribution.—White-rust is distributed throughout the world and attacks all crucifers.

Cause.—The disease is caused by a fungus (*Albugo candida* (Pers.) Ktz.) which enters the tissue of the host through the stomata, or breathing pores. Small oval spores are formed which are attached one to another in a beadlike manner under the epidermis. They finally escape by a rupture of the epidermis and are then easily wafted by the wind or carried on the body of insects to other plants. In the presence of sufficient moisture they readily germinate, the hyphæ finding their way into the stomata, or breathing pores, if lodged on the proper host. The disease is carried through the winter by the formation of thick-walled resting spores within the tissue of the host, from which they are set free the following spring by the decay of the plant.

SPOT DISEASE OF CAULIFLOWER.

This spot disease was first found to attack the leaves of cauliflower, but later was observed on cabbage to a more limited extent. It causes on the lower surface of the leaf, and less abundantly on the upper, small brownish to purplish gray spots somewhat irregular in outline. A puckering of the leaf results when the midrib and larger veins are badly affected.

Some loss was caused to cauliflower in tidewater Virginia during the spring of 1911, where 25 to 90 per cent of the plants in the worst cases were attacked.

This is a new disease of cauliflower and cabbage, due to a bacterium, as determined by Miss Lucia McCulloch, of the Bureau of Plant Industry, and no means for its control have been worked out. It has been observed that the spot disease is most severe during cool, damp weather, and is held in check when the warm, sunny days of late spring come on. In view of the fact that the organism is especially sensitive to sunshine and warm weather it is not likely to cause any serious damage except during protracted rainy, cool weather. Crop rotation should be employed in controlling it. So far as known the organism causing the spot disease of cauliflower and cabbage does not attack any other crucifers.

LEAF-BLIGHT (BLACK MOLD).

Description.—Leaf-blight is due to the fungus *Alternaria brassicae* (Berk.) Sacc., which may attack the plant at any stage of its growth. The vegetative part of the fungus lives in the leaf tissue of the host and under field conditions forms roundish black spots marked with concentric brown zones. These spots vary from one-fourth to one-half of an inch or more in diameter. The fungus may also live as a saprophyte and causes considerable damage to cabbage in the storage houses.

Control.—To prevent loss from this fungus in the storage house the following suggestions should be observed: (1) Disinfect the storage house by spraying the walls, benches, and bins with Bordeaux mixture; (2) exercise care in handling, so as to minimize injury to the heads; (3) maintain a temperature 1 or 2 degrees above freezing; and (4) keep the humidity as low as possible by proper ventilation of the house with outside air.

Distribution and loss.—Leaf-blight causes considerable damage to cabbage and collards in this country and in Europe. The greatest loss to cabbage occurs in the storage houses. The organism causing the disease is present in the houses under ordinary conditions, or it may be carried there with the cabbage when it goes into storage. It gains access to the tissue through wounds made by handling and cutting or by following up the tissue killed by other organisms. In the presence of plenty of moisture and a suitable temperature it develops rapidly, forming an unsightly black mold over the heads.

POWDERY MILDEW.

Powdery mildew is caused by a parasitic fungus (*Erysiphe polygoni* DC.) which forms a white powdery dust on the leaves of turnips and a few other plants. The loss caused by this disease is so slight that treatment is unnecessary.

DAMPING-OFF.

Damping-off is a disease of young seedlings and may be caused by any one of several species of fungi. It occurs mostly in the seed bed, where plants are growing in a crowded condition. It is rarely found in the open field. It is also a common disease in greenhouses, where a relatively high humidity is maintained and where the plants are protected from sunshine and free circulation of the air. The disease usually attacks the seedling on the stem at the surface of the soil soon after it comes through the ground. It soon girdles the stem and destroys the epidermis. The plant finally topples over and dies.

Preventive rather than curative measures should be employed for this disease. If damping-off has occurred before, the soil should not be used again, or if used should be sterilized according to one of the methods already discussed. Any method that will prevent the accumulation of too much moisture in the surface soil and reduce the relative humidity of the air about the plants is advantageous in preventing damping-off. This can be accomplished by practicing the following suggestions: (1) The upper layer of soil should be frequently stirred; (2) a free circulation of air about the plants and exposure to sunshine should be permitted; (3) the plants should be watered in the morning in preference to the late afternoon or evening; and (4) a layer of fine, heated sand should be sprinkled over the surface of the soil.

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